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14. ABSTRACT
The scientific and technical objectives of Pulse!! The Virtual Clinical Learning Lab are consistent with the original proposal; viz., to test whether game-based technologies provide learning environments for the acquisition of clinical knowledge and critical thinking leading to differential diagnostic skills for the practice of medicine. Selected patient physiological traits have been created and complex object functions have been scripted. A further technical objective was creation of case-authoring capabilities for use by game developers and medical faculty. The Case Authoring Tool also comprises tutoring functions that replicate clinical mentoring in the process of developing critical thinking and diagnostic skills.

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Technical Report
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Pulse!! The Virtual Clinical Learning Lab and Center of Excellence

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a. Scientific and Technical Objectives (limit 200 words/183)

The scientific and technical objectives of Pulse!! The Virtual Clinical Learning Lab are consistent with the original proposal (2005); viz., to test whether game-based technologies provide learning environments for the acquisition of clinical knowledge and critical thinking leading to differential diagnostic skills for the practice of medicine.

The program has been built with an iterative, play-based design that allows for continual prototyping and developing in a cyclical loop. This provides flexibility that allows creation of new scenarios replicating the changing world. Selected patient physiological traits have been created, and complex object functions have been scripted, as have collision information, artificial intelligence, path-finding and the use of motion-capture data.

A further technical objective was creation of case-authoring capabilities for use by game developers and medical faculty. The Case Authoring Tool (CAT) allows modification of existing cases and creation of new cases that utilize catalogs of virtual assets – patients, patient parts, equipment, environments and personnel – and physiological parameters reflecting a variety of case-based states. The Case Authoring Tool also comprises tutoring functions that replicate clinical mentoring in the process of developing critical thinking and diagnostic skills.

b. Approach (limit 200 words/189)

The fundamental approach of the Pulse!! project toward its scientific and technical goals has been that of creating a curricular delivery system for medical case interfaced with construction of virtual environments, physiological assets and case-authoring tools using state-of-thc art technologies common to the videogame industry but here appropriated for graduate medical education and allied health-care training. The development process has been integrated with a rigorous evaluation regimen to ensure the platform's reliability and validity as an environment within which medical and health-care learning can occur.

This case-based approach has incorporated subject-matter experts' expertise in the fields of medicine, computer-based virtual-reality, human factors and learning theory, all invested toward production of a virtual-world experience focused on skill sets to be mastered by health-care professionals. Case development has adhered to accepted protocols of medical training and education, including the Accreditation Council for Graduate Medical Education (ACGME), Pre-hospital Trauma Life Support (PTLS) and its subset, Tactical Combat Casualty Care (TCCC), among others.

Case-development has proceeded from the exterior body to interior anatomical processes

due to the likelihood that interior processes (e.g., fluid dynamics) are beyond the current reach of the videogame industry.

c. Concise Accomplishments (limit 200 words/170)

Concise accomplishments of deliverable demonstrations for this grant period include the following.

- Case-authoring tool (CAT): This component provides a broad range of modifications to existing cases. Work completed includes automation of asset management; design and development of a user-interface editor; design and development of a physiology editor; collection of user feedback on the toolkit and implementation of improvements based on user feedback.
- 3-D Scene Designer: This component increases the ability of developers to automate asset generation. Work completed includes enhancement of the environment editor; testing of the automated asset tool; collection of user feedback and implementation of suggested improvements.
- Tutoring system: This component provides automatic feedback to users as they work cases. Work completed includes refining the feedback system and enhancing the capabilities and accuracy of real-time task measurement and evaluation.
- Case-authoring assets: This task greatly increases options available to medical instructors in building their own cases. Work completed includes creation of new environments, including medical staff, patients, medical equipment and procedures; and research and design of new physiology assets.

d. Expanded Accomplishments: The Pulse!! Evaluation Plan (no word limit)

Verification and validation of the platform has been an integral part of the design and development of Pulse!! Human performance, instructional, human factors and evaluation experts are involved in all phases of Pulse!! design and helped drive crucial design decisions. This approach has been truly iterative as prototype versions of the system were made available, evaluated and resulting data fed back to improve design. Moreover, a multi-phase summative and formative evaluation plan was devised and has been implemented since the program's inception. The plan included multipurpose evaluation activities, and it was designed to determine the reliability and validity of the Pulse!! platform as a medium for medical education and training. The multi-component evaluation strategy was shaped to measure outcomes. Results indicate that the Pulse!! learning platform is reliable and valid as a delivery system and teaching strategy for curricula in the health professions.

There have been 10 studies at five sites, including: National Naval Medical Center Bethesda, Yale University School of Medicine, The Johns Hopkins School of Medicine, Baystate Medical Center-Tufts University School of Medicine and the Emergency Medicine Residency Program at CHRISTUS Spohn Memorial Hospital, an affiliate of the Texas A&M University Health Science Center. Five physicians, one at each site, were co-primary investigators for evaluation of the Pulse!! platform. The sample (n=100) was composed of senior physicians, fellows, residents and medical students. Power analysis for a 2x2 chi-squared statistic was calculated using a power level of .80 and an estimated effect size of .50. The required sample size indicated by the power analysis was either met or exceeded for each evaluation category.

Results from all studies found strong, significant effects that support the use of the Pulse!! learning platform; thus, the studies' results can be viewed with confidence that the platform is a reliable and valid teaching/training tool.

The evaluation plan called for several categories to be assessed with methods other than research studies. Components assessed were system design, learning features, usability and training effectiveness, as noted below with analytical method and outcomes.

System design

Assessing the soundness of system design included a variety of evaluation questions to ensure that the system was developed as planned and can be easily used by trainees. Aspects included determining whether the underlying physiological models were valid and whether they interact with one another in a realistic way; comparing system functionality to design specifications to ensure that the platform performs as intended; and ensuring that basic usability issues are resolved.

Based on a thorough analysis of the system design approach and resulting system, it was verified that the Pulse !! platform was developed in accordance with system specifications. Physiological and mathematical models were subjected to an iterative review process that included several subject matter experts until it was determined that the models were accurate and sufficiently robust to meet the project's goals.

Learning features

Assessing the degree to which the system incorporated sound learning features uses extant literature in the science of learning, synthetic experience, game-based learning and scenario-based training as a guide to determine that the system embodies sound learning strategies and features. These included the following:

- Specific, measurable learning objectives;
- Appropriate scenario design, including trigger events;
- Sound instructional strategies/elements;
- Accurate performance assessment and data recording strategies;
- Sound diagnosis routines and models;
- Appropriate feedback and after-action review strategies.

Early in the development process, several mechanisms were put in place to ensure that learning objectives were appropriately addressed in design. This resulted in matrices that lay out learning objectives and then specify in detail with task-analyses how objectives are represented in the platform. Working with project personnel, subject matter experts and programmers, the evaluation team helped guide scenario design to ensure that appropriate cues were available to learners as they worked through the cases.

Usability

Establishing the usability of the system includes both the effectiveness of the user interface, i.e., how easy it is to learn, how easy it is to navigate, how long it takes to master and the quality of tutorial material; and "playability," i.e., the extent to which the training provides a

pleasurable, challenging, fun environment for learning. This aspect is crucial to the idea that learners will be intrinsically motivated to engage in the instruction because it has inherently motivating qualities.

Usability testing proceeded down two paths. First, the basic question of whether users would be able to use the system easily, find it intuitive. To address this question, a usability study with subjects from two teaching hospitals in the Northeast was conducted. Subjects were drawn from a variety of medical specialties and experience levels, from medical students through senior physicians, to ensure that the interface was usable across a variety of learner and experience levels. Through systematic observation, trained evaluators concluded that the basic interface was usable and intuitive.

A "playability" study from a third teaching hospital was designed to test specific aspects of the interface. In this case, the evaluators gave each participant a specific set of tasks to complete within the platform. The participants' ability to complete each task was timed and outcomes noted. These data, along with information from earlier studies were fed back to developers so that appropriate improvements to the interface could be completed. The results support the Pulse!! platform as a viable environment in which to embed instruction. Participants responded well to the technology and were able to use the system quickly.

Training effectiveness

A modified version of Kirkpatrick's hierarchy, used extensively throughout industry and the military to assess training effectiveness, provides the framework to assess the following elements.

Pre-training assessment determines the degree to which the trainee is prepared to benefit from the training. Research has shown that trainees who lack the cognitive or affective prerequisites for training do not perform as well as trainees who are better prepared. Assessing readiness for training can indicate whether trainees need remedial attention prior to entering training or how training might be tailored to specific needs; e.g., by starting with less challenging scenarios. The sample (n=100) was screened for participation through the collection of demographic data by survey instruments administered prior to training. These data were evaluated by subject-matter experts.

Reactions/motivation measures are the most common method of measuring training effectiveness but not necessarily the most informative. Research has shown that simple reaction measures are not necessarily correlated with actual learning. This does not mean that motivation is unimportant; only that reaction measures, by themselves, are insufficient. In addition, reactions that involve trainees' beliefs about the value or utility of training have been shown to predict performance better than affective reactions. Hence, measuring reactions was recommended for the Pulse!! project.

Reactions/motivation. Reaction data on the same sample was collected to determine whether users would find the system to be useful and engaging. Results indicated that the overwhelming majority (82%) of participants reacted positively to using the Pulse!! platform. Over 80% also reported that engaging in the platform held their interest, and all but one respondent reported that the platform was visually appealing.

Learning, defined as permanent cognitive change, is the second most popular training effectiveness measure, and it is typically assessed via paper and pencil tests; and in this case,

through one of several candidate strategies to assess expert knowledge organization. Before a learning study could be completed it was first necessary to validate metrics that would be used to measure performance. To do this, an "expert referent" was compiled using input from subject-matter experts. The expert referent was then used to create calibrated videotapes of four levels of performance, which were presented to thirteen faculty physicians at two teaching hospitals in the Northeast (all participants had extensive experience in trauma management). Specifically, one tape showed nearly perfect performance, two showed performance that required improvement, and one showed performance that was unacceptable. The question was whether faculty physicians would correctly distinguish the different levels of performance. Results indicated a high level of agreement in how participants rated performance in the tapes. This provided evidence that the expert referent was valid and could be used as a basis to assess performance in learning studies.

The initial test of learning effectiveness was conducted on medical students and residents from teaching hospitals in the Northeast and South. Results indicated that training trauma life-support procedures using the Pulse!! platform (with appropriate feedback) is superior to paper-based learning methods, in which students read what an expert would do and mentally simulated the scenarios. For example, students who experienced the Pulse!! platform were less likely to commit errors involving the airway ($X^2 = 5.94$, $p < .05$); breathing ($X^2 - 5.84$, $p < .05$); Disability ($X^2 = 10.96$, $p < .01$); and secondary survey ($X^2 = 5.05$, $p < .05$). Pulse!! users also made fewer total errors ($t = -4.44$, $p < .05$). Moreover, statistically significant differences were found regardless of the data collection site or demographics of the learner ($t = 0.67$, $p = n.s.$). Distribution analyses indicated no significant differences in the distribution of errors among any of the sites ($F = 1.11$, $p =$ n.s.).

Transfer of training, learning and training behavior is a complex phenomenon to measure. Data are collected from a variety of sources (e.g., supervisors, peers, archival records, etc.) and augmenting quantitative measures with surveys determine whether barriers to performance exist in the operational setting. *Training behavior* refers to the extent to which the trainee can demonstrate mastery of crucial skills. Training behavior is typically measured through work sample tests or simulations. The nature of the Pulse!! learning system means that this kind of assessment can be done relatively easily by preparing several test scenarios that contain no hints, feedback or other performance enhancing features.

The study hypothesis was that subjects who receive trauma management training in Pulse!! will outperform those who receive standard paper-based training. Researchers used a chi-square analysis with subjective impressions to assess the likelihood of errors in trauma management as a function of the training group (Pulse!! v. paper-based training). Participants across four sites who received trauma management training in Pulse!! outperformed those who received paper-based training. Pulse!!-trained participants made significantly fewer errors on trauma management procedures.

Conclusion

Based on significant and robust findings, Pulse!! has been shown to be a reliable, valid teaching tool that can be used across the spectrum of personnel in Navy medicine, education and training. The learning platform can be used with confidence in the Navy and Defense health system.

e. **Work Plan for Next Reporting Period (limit 500 words)**
No work plan has been developed. The project is closing out.

f. **Major Problems/Issues (limit 250 words)**
No major problems or issues were encountered in this period of development.

g. **Technology Transfer (limit 500 words)**
None in this funding period.

h. **Foreign Collaborations and Supported Foreign Nationals**
None in this funding period.